NOTES ON THE GEOLOGY OF THE MT. FLINDERS AND FASSIFERN DISTRICTS, QUEENSLAND.

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(Plates i.-vi.)

Mount Flinders is a rugged peak attaining an altitude of 2,240 feet, and situated about 11 or 12 miles S.S.E. of the town of Ipswich, Queensland. Surrounding the main peak there are a number of smaller cones and rugged rocks, most of which represent remnants of former parasitic vents or smaller foci of eruption which encircled the large volcano.

The rocks composing the main peak are felspar-porphyry, trachyte, trachyte-breccia, tuffs, and occasionally a little andesite, dacite, and dacite-breccia. The smaller cones consist likewise of trachyte-breccia and andesite, and some of the most rugged rocks (see fig 8) consist of a plug of trachyte or trachy-rhyolite. The andesite is not by any means abundant, and may be looked upon as merely a more basic phase of the trachyte. It occurs here and there interbedded with or overlying trachyte-flows or sheets of breccia.

It is noteworthy that the conical mountains are usually composed of breccia, with more or less of basic trachyte, dacite and andesite; and, further, they are characterised by better soil (usually of a red or brown colour), and a thicker vegetation; patches of vine-scrubs occur on them.

The Physiography of the surrounding Region.

To the north of Mount Flinders lies the Coalfield area of Ipswich and Bundamba, which has been described in a Report by Mr. W. E. Cameron, B A.* This area forms part of a series of

* Geology of the West Moreton or Ipswich Coalfield. Geol. Surv. of Queensland, Rep. 1899.

sandstones, conglomerates and shales to which the name "Ipswich Formation" has been given; and which, from the fossil plants contained in it, has been referred to the Upper Trias-Jura. The whole series has been greatly faulted and folded, the folding in some cases being due to compression of trough-faulted blocks. Here and there basalts have burst through the fissures and covered considerable areas. Such is the case at Booval, near Ipswich. In Ipswich proper a hill known as Limestone Hill is capped with a deposit of secondary limestone and siliceous sinter. These substances are leached out of a mass of decomposed basalt and basaltic tuff, which has been extruded from a curved fissure. In other places basaltic cones of considerable height may be seen, as Mt. Forbes or Walker, about 15 miles S.S.W. of Ipswich. This mountain intrudes the Walloon Series, the newest of the Ipswich Formation, and flows from Mt. Walker cap the Walloon Series over considerable areas. To the west and south-west of Ipswich the Coal Measures are not so faulted and tilted as at Ipswich. These Coal Measures form the Walloon Series, which is separated, according to Rands and Cameron, by a probable line of fault running N.E.-S.W from Fernvale in the direction of the Flinders Mountain group. Towards the N.W., this fault forms the border between the Palæozoic rocks of the Parishes of Burnett and Sahl* and the Walloon Series. The Brisbane River, although it meanders into the Ipswich Formation, in places has a tendency to follow this fault through some part of its course. After the Brisbane River has swerved to the east, flowing north of the Pine Mountain inlier, the fault continues in its original direction separating Pine Mountains from the Walloon Series, and further to the S.W. Deebing Creek practically flows parallel to the fault-line.

This fault is of importance in the discussion of the geology of Mt. Flinders because the mountains of the Mt. Flinders group lie to the east of it in the intensely faulted and crushed strip of country which lines the eastern side of that fault. In this strip

* See Cameron's map No.2 of the Ipswich Beds.

the dip is generally S.W. or W.S.W. at moderate or high angles. To the west of the fault most of the observed dips are at low angles (Walloon Series). If this fault were absolutely linear, it would pass almost through the summit of Mt. Flinders, but, from the tendency to strong westerly dips west of Mt. Flinders, it is concluded that the main fault swings round to follow a more meridional direction.

The Walloon Series are so slightly inclined that outcrops are seldom met with. The Coal beds, which are mined near Ipswich, probably occur here at considerable depth. The preservation over this area of the newer beds of the Ipswich Formation is due to their downthrow, and the older Series has been exposed east of the great fault-line by faulting and overthrust-folding. In the Parishes of Thorn, Normanby, and Fassifern, west of Mt. Flinders, the Coal Measures belong to the Walloon Series and are extensively covered with basalt-flows. The faulting, which is so extensive in the Ipswich district, probably dies out to the south of Mt. Flinders, or at all events it becomes less pronounced; it appears to me to be due to the fracturing of an anticline by faults parallel to its axis. South and south-east of Mt. Flinders a number of rather flat-topped hills exist, which I take to be remnants of the anticline. These hills consist essentially of sandstone with or without capping of dark trachyte-lava or basalt, and they form in part—*i.e.*, north of Mt. Flinders—the watershed between the tributaries of the Bremer River and those of the Logan River.

Still further to the south-east we get to the Beaudesert district; here, too, we meet with Coal Measure sandstones, often altered to hard quartzites by doleritic intrusions, and extensive areas are capped with basalt-flows. The basalts and dolerites around Beaudesert are covered with rich black soil which was originally partly scrub-land and partly forest. The chief forest-trees on the formation are *Eucalyptus tereticornis* and *E. maculata*; on the hills also are *E. crebra*, *E. melanophloia*, *E. hemiphloia* and *E. tesselaris*.

The geology of this region has, to some extent, been discussed by W. H. Rands in his Report upon the Albert and Logan Districts, 1889. In that Report Mr. Rands refers to a fine sanidine-trachyte, "apparently interbedded with" the Ipswich Coal Measures, near Walton Station. This is the only place in the district where Mr. Rands met with trachytes. On my own visit to the district I unfortunately did not see the locality, for neither do the maps show, nor could anybody I asked at Beaudesert tell me of, such a place as Walton Station. The occurrence referred to by Mr. Rands is probably not a truly interbedded sheet but a fine-grained sill.

Although the main object of my investigation in the present paper is Mt. Flinders and the immediate neighbourhood, yet on the present trip I extended my researches to a review of the interesting volcanic rocks of the Fassifern district, of which I hope later to make a closer study. In all my field work I have had the benefit of the advice of Mr. Wearne, B.A., Principal of the Ipswich Technical College, who is an excellent geologist and is intimately acquainted with the district.

The most fertile part of the Fassifern District is known as the Fassifern Scrub, which has a diameter of about eight miles. This area was originally covered with a dense jungle of vine-scrub, though now most of it is under cultivation; and the strange thing about it is that the underlying rock is essentially trachyte. The trachyte-masses intrude sandstone of a very calcareous nature, and are associated with trachyte-tuffs and were followed by eruptions of andesitic basalts. The basalts of the adjoining districts are forest-covered, the chief timbers being Ironbark (*E. melanophloia* and *E. crebra*), and Blue Gum (*E. tereticornis*). We have, therefore, at Fassifern the inverse of the usual order of things. Generally the basalts have scrub and the trachytes forest, but here the trachytes have scrub and the basalts forest.

The dense vegetation of the trachytes of the Fassifern Scrub is due to three main causes :—

1. There is a mixture of soils derived from alkaline trachyte, from calcareous sandstone of the Walloon Coal Measures, and from the numerous dykes of basalt which intrude the trachytes.

2. Decomposition of the rock is faster than usual, because of its rather coarse texture, the fair average rainfall (30 inches per annum), and the abundance of springs in the trachyte area.

3. Much of the soil is derived from tuffs and breccias

Absence of scrub on the basalts here is due to the same cause as in other western localities, viz., the rainfall is too irregular to sustain a scrub in the absence of springs.

The volcanic rocks of the Fassifern Scrub are all Post-Triassic and probably Post-Cretaceous. There seems to have been an old series of dolerites anterior to the trachytes, but I have not satisfied myself on this point. The remaining links of the sequence, viz.—(1) Trachyte, later (2) Andesite, and still later (3) Basalt.—I have found satisfactory evidence for.

All the volcanic rocks of the Fassifern Scrub may be looked upon as belonging to the denuded remnant of one great volcano, a fraction of which remains in Mt. French. The latter consists of massive columnar trachyte; some of the columns reach a length uninterruptedly of some 250 feet. The columns of the North Peak are vertical, and this part of the mountain is probably a flow.

To the W.S.W. of Mt. French lies Mt. Edwards, which likewise consists of columnar trachyte. South of Mt. Edwards lie the peaks of Mt. Greville and Mt. Alford, both consisting of trachyte and quartz-trachyte. All these are isolated peaks, the plugs of independent denuded volcanoes. On these mountains and on the summit of Mt. French the vegetation is of a poor forest-type as in the Glass House Mountains. The trees which follow the trachytes are Ironbarks (*E. crebra* and *E. melanophloia*) and Moreton Bay Ash (*E. tesselaris*). On the poor, very siliceous sandstones which occur west and south-west of the Fassifern Scrub, the forest-trees consist of Spotted Gum (*E. maculata*), Blue Gum (*E. tereticornis*), Ash (*E. tesselaris*), Wattle (chiefly *Acacia decurrens*), Box (*E. hemiphloia*). On the richer flats and on hills which are cut by dykes, occasional Bloodwoods (*E. corymbosa*), occasional Dogwood-trees (*Jacksonia scoparia*), and, near water-courses, Apples (*Angophora intermedia* and *A. subvelutina*), Ironbark (*E. crebra*), and *Callistemon* or Bottle-Brush.

To the south of the area in which all these trachytic mountains occur, and lying between this area and the McPherson Range, there are numerous steep peaks, and ridges, and ranges which are of rhyolitic composition, according to Mr. Wearne, who has shown me beautiful rhyolites and obsidians from this district. The rhyolitic mountains comprise the McPherson Range, Mt. Maroon, the Maroon Range, Mt. Barney, and Mt. Toowoonan (the last-mentioned may be composed of trachyte). It would seem that the period of eruption which gave trachytes in the Fassifern District, gave rhyolites in the McPherson Range area. Basalts have followed in both areas.

From Engelsburg, in the Fassifern District, I visited, accompanied by Messrs. Wearne, McGrath, and Johns, the Little Liverpool Range. We ascended the range along the Old Warwick Road, and reached a point between Spicer's Peak and Mt. Mitchell, about 23 miles from Engelsburg. A section showing the structure of the range (not to scale) is given in fig.1.

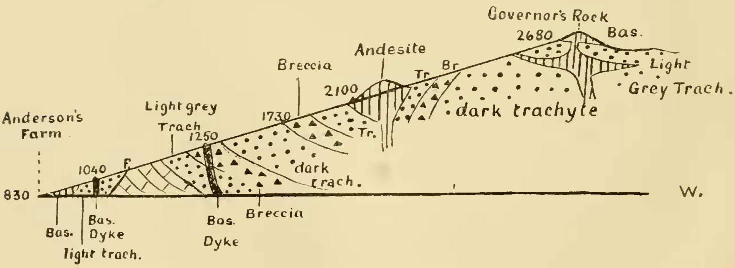

Fig. 1.—Diagrammatic representation of the formations met with in ascending the Little Liverpool Range along the Old Warwick Road

The whole range is apparently due to a gigantic trachyte fissure-eruption, which has emitted flows of light grey trachyte, sheets of breccia and tuff, dark trachytes and trachy-andesites. Later eruptions of a more localised and less intense nature emitted andesite, which in some places has burst through the trachyte. Still later, eruptions simultaneous with those which emitted the enormous flows of basalt on the Darling Downs, gave rise to dykes and sills, intruding also the trachyte. These Darling Downs basalts have been blocked on the east by the trachytic range. That the focus of the volcanic activity is near the core of the range is seen by beds of breccia containing blocks up to 24 inches in diameter, occurring half-way up. The forest on the breccia-formation consists of *Casuarina*, Bloodwood (*E. corymbosa*), Blue Gum (*E. tereticornis*), Stringybark (*E. acmenioides*), Tallow-wood (*E. microcorys*), Moreton Bay Box (*Tristania conferta*), Apple (*Angophora subvelutina*), Ironbark (*E. melanophloia*), and Grass-tree (*Xanthorrhœa*).*

The culminating peaks of the range, like Spicer's Peak, Mt. Mitchell, Mt. Cordeaux, Mt. Huntley, Mt. Roberts, &c., are apparently of trachytic composition; and almost all the eastern fall of the range is essentially trachyte, but the western fall and the top of the range (excluding the peaks) have considerable patches of basalt. I have good reason to believe that the whole of the Little Liverpool Range, from Wilson's Peak to the Rosewood District, is mainly trachytic; and that this range is built up along a great fault running N.N.W.-S.S.E., following a line which, in Triassic and Cretaceous times, played a similar part to that probable fault running from Dubbo to Narrabri in New South Wales. During Triassic times sedimentation took place mainly to the east of this line; during Cretaceous time subsidence took place to the west of it, with the result that sedimentation took place mainly over this part of the country. In Post-Cretaceous times a great horizontal uplift took place, or perhaps, as Suess would have it, a negative movement of the sea; this was followed by faulting, which led to the formation of a trough in which the Ipswich Formation is preserved. This trough would be encompassed between two faults, A and D, the one, D, separating the subsided area from the Brisbane schists, and A, separating the area from the stable or elevated Darling Downs. (Figs. 2 and 3.) Had the downthrow of the Ipswich Measures been earlier, we should have expected more Cretaceous sediments deposited over the Ipswich Measures.

* I am indebted to Mr. McGrath for the identification of many of the forest-trees.

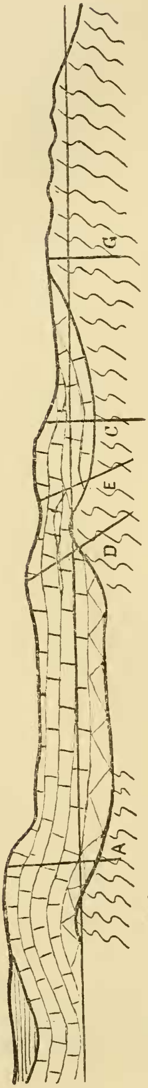

Fig. 2.

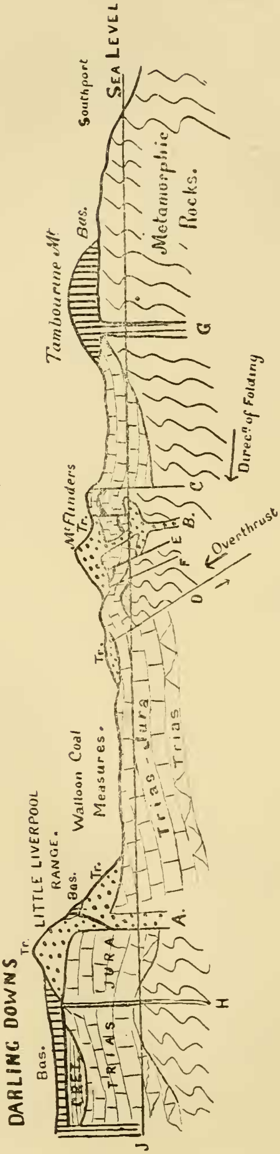

Fig. 3.

Fig. 2.—Ideal section from the Darling Downs to the sea, after the upheaval following the period of Mesozoic sedimentation and before the period of faulting and volcanic extravasation. A, D, E, C, G represent the chief lines of weakness where faults subsequently formed. Hatching as in fig. 2.

Fig. 3.—Ideal section from the Downs to the sea. A, H, J, B and G are volcanic pipes; D, F, E, C, faults.

Cretaceous sediments occur occasionally in the Ipswich Coal Measure area, but only as very small localised lenticular patches which represent deposits formed in lagoons or river-channels. In Cretaceous times the drainage must have been from east to west. Further faulting, as between C and D, has led to the compression of some parts, leading to the intense folding and overthrusting at Ipswich.

Some processes of this kind must have given rise to the structures observed between the Brisbane schists and the Darling Downs.

Another point worthy of comment is that, with the exception of the Brisbane River, all the watercourses in S.E. Queensland roughly follow the structural lines, such as faults, anticlinal axes, &c., and run N.N.W.-S.S.E. or N.-S., or more rarely N.N.E.-S.S.W. Such is the case with the Brisbane and Bremer Rivers above Ipswich, the Logan and Albert, Deebing Creek, the Stanley River, &c., &c. These streams are all subsequent. A somewhat recent elevatory movement in part of this area has effected certain changes in the drainage; Mr. Wearne informs me that old river-channels filled with sand and gravel sometimes interrupt the working of a coal seam.

Most of the valley of the Bremer River presents the features of mature erosion. Likewise the Teviot Valley is mature, except for a small part where it receives Woollaman Creek and Undallah Creek as tributaries. Here it flows through hilly country, and I consider this region to have been slowly and recently elevated, river-erosion having kept pace with elevation. It is a strange thing, which cannot be explained on other suppositions, that the watershed between the Bremer and Teviot is almost in old age, whilst all the Teviot's tributaries flow for a short distance through rugged hilly country, even those which rise in the perfectly mature area. It is evident that the Brisbane River is a fairly young stream as regards its lower course. It is only just entering upon its mature stage; but many of its important tributaries are mature. The nature of the beds through which they flow partly accounts for this, the tributaries carving their valleys in soft sandstone, the main stream in hard schists. There is an immense amount of valuable work to be done in working out the history of the drainage of South-eastern Queensland.

So much for the physiography of the districts around Mt. Flinders. The main facts to be gleaned may be summarised as follows : —

1. Mt. Flinders is an isolated trachytic volcano.

2. It rises out of inclined and highly faulted Trias-Jura formation, which it has broken through. The intense folding observed in this belt of country is due to the crushing of the faulted portions.

3. Trachyte becomes more abundant as the south-western border of the Ipswich Formation is reached near the New South Wales border, viz., in the Little Liverpool Range.

4. The trachytes here probably fill a gigantic fissure. Evidence pointing this way was found in the presence, in the trachyte, of masses of sandstone altered to quartzite, and often these blocks of included quartzite show slickensided structure on the surface.

Detailed Account of Mount Flinders.

The main peak of Flinders consists, as show in figs. 4-5, of a plug of felspar-porphyry, which is surrounded and capped by trachytic breccias. These occur on the mountain all round the summit at a height of 1,800 feet, and the breccia-zone is marked all round

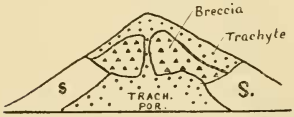

Fig. 4—Sketch-section of Mt. Flinders as before erosion.

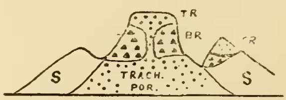

Fig. 5—Sketch-section of Mt. Flinders after erosion.

by a circlet of large caves. In one of these caves, on the south side of the mountain, fibrous alum fills the joint-cracks, and occurs as an excrescence on the rock. This is, probably, because the rock (breccia) is rich in sulphur, which by some process is being oxidised, and is reacting with the products of decomposition of the felspar. Right on top occurs the normal alkaline trachyte.

This, as well as breccia, may also be found on all the spurs from the main plug. In the immediate vicinity of the mountain occur several smaller knobs, which clearly represent remnants of flows from the top of Mt. Flinders, which have been isolated by streams undermining them by working into the underlying breccias. As the map shows (plan fig. 2), the Flinders Peak is surrounded by numerous smaller mounts, such as Ivory's Knob, Mt. Goolman, Mt. Blaine, Stafford's Knob, Green Knob, Mt. Elliott and Dwyer's Knob. Each of these peaks was an independent focus of eruption.

Ivory's Knob, as the photograph shows, (Pl.v. fig.1) is a rugged pinnacle. On examination it was found to consist of breccia made up of fragments of trachyte, sandstone, chert, &c., cemented firmly by dykes and stockworks of trachyte-lava which had been injected into the breccia. Rhyolitic trachytes must have flowed from the crater of this volcano, and a remnant of a breccia-sheet, capped with a flow of spherulitic obsidian, occurs in Kelly's paddock, Selection 218, Parish of Goolman.

Stafford's Knob is simply a plug of rhyolitic trachyte. A little tuff occurs near its base.

Dwyer's Knob I did not get to, but its structure appears identical with that of Stafford's Knob.

Mt. Goolman I did not go to, but it appears similar to and intermediate in structure between Mt. Flinders and Mt. Blaine.

All the foregoing have a poor grey soil and wretched forest vegetation.

Mt. Blaine is largely covered with scrub. This is due to the fact that this mountain is mainly composed of breccia, covered with flows of amygdaloidal andesite. The core is, however, trachytic. The andesite and quartz-dacite are merely a basic phase of the trachyte, and I could find no evidence to show whether they were erupted early or later than the true trachyte. The soil of Mt Blaine is brownish, and Pine (*Callitris* ?) is a characteristic timber.

The Green Mountain has a similar conical appearance and brown soil; the vegetation on it is, however, less luxuriant; and, as far as I could judge, its component rocks were breccia and dark ægirine trachyte-flows.

Mt. Elliott and similar smaller cones present close resemblance to Green Knob.

All these plugs may best be considered as parasitic vents of the great volcano of Flinders. Thin flows from this group must have extended six or seven miles to the west, for isolated remnants overlying sandstone with petrified wood, occur near Peak Crossing. Dykes also occur, as on Selections 44 and 47. Basalts appear to cap trachyte in places near Peak Crossing, but they have been emitted from a different focus of eruption. No true basalt occurs on the tops or slopes of the Flinders mountains. The trachytes mentioned by Rands as occurring between Logan Village and Beaudesert, near Walton Station, are probably genetically connected with those of Mt. Flinders, which cannot be 20 miles distant.

Between Mt. Flinders and Mt. Blaine, near Perry's house (Selections 103 and 107) numerous faults were noticed in the creek banks (Sandy Creek). Sudden changes of dip occur, but the dominant direction of dip is west. The abundance of faults in this locality is noteworthy (fig.2).

Supplementary Notes.—In figs. 2-3 I have tried to offer an explanation of the geological structure of South-east Queensland, which has metamorphic rocks fringing the coast and the late Mesozoic rocks forming a tableland 2,000 feet high inland. On the Darling Downs we have the Upper and Lower Cretaceous, and the whole Jurassic and Triassic underlying the Tertiary (Pliocene ?) basalt-flows. East of the Darling Downs over the Ipswich Formation no Cretaceous beds occur, except a few lenticular patches of small area, containing a few fossil fishes and fossil plants of fresh-water origin. These small isolated outliers are always of such shape that it is evident that they are deposits formed in lagoons and river-beds. It is quite possible that they are of Post-Cretaceous age.

It appears, therefore, that in Cretaceous time there was land east of the position of the Little Liverpool Range, and sea to the west of it. Yet that old sea-area stands now 2,000 feet higher than the old land-area. How can we explain this phenomenon? Evidently at the end of the Cretaceous period the Cretaceous sea dried up, and its basin was uplifted, the expansion of Triassic and Jurassic sediments aiding to bring about vertical uplift.

Possibly, as the sketch (figs, 2-3) suggests, the Ipswich and Walloon Measures participated in the uplift and folding, which, however, were greatest over the Downs basin, where sedimentation was thickest. Why now have we the Walloon coal-measures, which, on the Darling Downs, immediately underlie the Cretaceous, lying about 2,000 feet lower in the Ipswich area than in the Downs, and dipping west in under the Darling Downs? Either the Walloon measures are very thick, exceeding 2,000 feet, and a considerable thickness has been removed by erosion east of the range, or a Post-Cretaceous fault has lowered the whole area over which they now outcrop by about 2,000 feet.

The first hypothesis I object to on the following grounds:—

(1) I believe that 2,000 feet is an overestimate of the thickness of these beds.

(2) If this area was land in the Cretaceous, as it appears to have been, the slight angle of dip of the beds of the Walloon series, and the continuation of apparently the same beds higher up in the Darling Downs tableland, and the existence of what are looked upon as Cretaceous deposits in patches formed by aggradation, are facts implying that the area formed in Cretaceous times a lowlying coastal plain fringing Cretaceous sea, and that it consequently did not suffer extensive Cretaceous erosion. But in early Tertiary times a fault developed and the country west of it was progressively raised, and that east of it depressed. Simultaneously volcanic outpourings overspread the plains on both sides of the fault. Thus we have trachytes, trachyte-tuffs, basalts, and andesites capping the Walloon coal-measures in many places. These lavas probably commenced to be erupted in Eocene times, and have protected the underlying Trias-Jura from Tertiary erosion. If Tertiary erosion had been very pronounced, it is doubtful whether any Eocene tuffs would have been preserved to

tell the tale of volcanic eruptions. Only the plugs of extinct volcanoes would have been left.

Being a low, inland plain, situated between the Palæozoic coastal hilly country and the upraised Darling Downs, the Ipswich-Fassifern district was protected from extensive Tertiary erosion.

We see, then, that the country east of the Darling Downs has probably been depressed by early Tertiary trough-faulting. The Ipswich area was greatly fractured and overthrust. The area covered by the Walloon coal-measures subsided in a block, and, being practically a broad, belted coastal plain at the outset (in the late Cretaceous), and being by progressive subsidence lowered to the new base-level before its configuration could be interfered with by eastward-flowing streams, it has preserved an old and mature appearance which is only disturbed by Tertiary lava-domes, and Tertiary folding in the Ipswich beds.

Petrology.

1. *Pyroclastic Rocks.*—In the Little Liverpool Range a trachyte-agglomerate or breccia, with boulders up to many tons in weight, is a rock of common occurrence. Basic tuffs and breccias have also been observed in places. At Mount Flinders and on the slopes of Mt. Blaine considerable areas are covered with a breccia intermingled with lava which has a brecciated structure, having swept up fragments of the underlying breccia. Some of the breccias are distinctly trachytic, others appear andesitic.

The lavas interstratified with the breccias on Mt. Flinders and Mt. Blaine look like the dacites of Bankfoot House in the Glass House Mountains. Quartz and oligoclase are common constituents in them. Zeolites, pseudobrookite, magnetite, and ilmenite also occur. In addition, the usual trachyte-felspars, sanidine and anorthoclase, are quite common, and the groundmass is generally a dark, often black, cryptocrystalline to glassy lava, frequently with microspherulitic structure well developed in it.

Globulites, margarites, axiolites, crystallites, and spherulites are very common structures in these hypohyaline brecciated lavas.

The breccias and tuffs contain an abundance of characteristic boomerang-shaped, bone-and-knuckle, and dumbbell-shaped glass-fragments.

These pyroclastic rocks were all formed subsequently to the period of extrusion of the comendites and trachytes, and at the commencement of the andesitic and dacitic eruptions.

Fl.15. Loc.: Alum Cave, Mt. Flinders.

Light white to greyish brecciated rock which has bluish stains (smaltite) and bright pinkish-red (erythrite) stains due to cobalt. In handspecimen it is seen to be made up of fragments of all sizes imbedded in an aphanitic groundmass.

Under the microscope the fine groundmass may be seen to be composed of fragments of crystals and microlites firmly interlocked. Nepheline is an abundant constituent, as is also orthoclase (or anorthoclase). This part of the rock is a tuff.

On examining the inclusions some are found to consist of tuff and breccia, others of cryptocrystalline, pseudospherulitic lava. The latter exhibits micropœcilitic fabric; numerous areas which, in plain light, seem to be made up of a dense felt of minute crystallites, extinguish together; the reason obviously being that certain areas which have a felspar-composition but are crowded with minute inclusions, have crystallised out either primarily or by devitrification. As these areas have consolidated under pressure, they do not possess crystalline outlines, but the abundant inclusions present, nevertheless, give them the appearance of being divided up into crystals.

Felspar is the main component of both tuffy and lava-portions. Next in amount we have the feebly birefringent to isotropic minerals which consist of globulites, crystallites, &c., together with areas of felspathoid. Differentiation between them is rarely possible. Next in abundance we have the nepheline which can be recognised as such. It occurs as hexagonal and prismatic sections showing cleavage at 60°, and characteristic refractive index and double refraction. Next we have a clear colourless or faint bluish mineral with the R.I. of topaz, and a D.R. of about 0·030. It occurs associated with decomposing nepheline and felspar. It shows an hexagonal cleavage like nepheline. It is in all probability katapleite. In still smaller amount we have a yellow amorphous mineral which stands in medium relief, and has a very low double refraction. This does not show the peg-structure of melilite, yet it may be melilite. It may also be perhaps eudialite. Cancrinite occurs associated with nepheline and katapleite, and is distinguished from the latter by its low index of refraction. Complex twinning is another characteristic of the katapleite. Nosean appears also to be present, associated with the same decomposition-products.

This rock contains veins of alum. The alum is derived from the decomposition of some mineral like nosean, or from some sulphosilicate like microsommite.

From the nature of the contained minerals we must call this rock "phonolitic breccia."

2. *The Trachytes.* (*a*) Comendites.—Rocks belonging to this family occur abundantly on Mt. Flinders, Mt. Blaine, and surrounding pinnacles, and on Mt. French and on the Little Liverpool Range. The following has been selected for detailed description.

Fl.17. Macroscopically, a fine-grained, aphanitic, white rock, occurring as gigantic vertical columns extending to the summit of Mt. French.

Microscopic examination : texture, holocrystalline, microcrystalline with orthophyric fabric. Composition : the essential minerals are felspar and quartz. The minor constituents comprise arfvedsonite, secondary magnetite, peropkite(?), chalcedony, and tridymite(?). The felspar is chiefly of the isometric or almost isometric form, though some is prismatic. It is the most abundant mineral, amounting to about 70 % of the rock. It possesses the usual properties of sanidine, and is partly idiomorphic and partly allotriomorphic. Quartz comes next in order of abundance. It occurs chiefly in the form of idiomorphic prisms, hexagonal in section, and forms about 20 % of the rock. There is also present allotriomorphic quartz and chalcedony. The chalcedony occurs chiefly as irregular masses infilling cavities which were originally miarolitic. Each mass has a brownish rim, and a faint yellow interior which frequently has a fibrous radial or banded structure. The brownish rim has a double refraction of about 0·020, and a higher refractive index than canada balsam, hence probably contains a variety of serpentine. The yellow portion is sometimes isotropic, sometimes feebly birefringent in a spherulitic manner, being optically an aggregate of spherulites. Its refractive index is higher than that of canada balsam. It consists undoubtedly of chalcedonic silica and opal. That these secondary minerals infill cavities is shown by the fact that the quartz and felspar of the rock always present idiomorphic faces towards them. Included in the chalcedony masses there frequently occur minute coin-shaped or hexagonal plates which are perfectly clear, colourless, and almost isotropic, and have a very low refractive index. This mineral is tridymite, and it occurs also in small amount in other parts of the rock. Soda-amphibole amounts to less than 5 %. It is of a dull, slaty-green colour, possesses the characteristic amphibole cleavage, and occurs in allotriomorphic corroded crystals which, in general, present straight edges in the cleavage-direction. The extinction angle with the cleavage on the face $b(\mathfrak{c} : c')$ is 14°. Pleochroism is strong and well marked. On sections showing only one cleavage, the pleochroism may be from blue-black to green, or from green to yellowish-brown. On sections perpendicular to the prism-zone, the colour changes from olive-green to opaque blue-black. As $\mathfrak{a}$ lies near the c' axis, the absorption-scheme works out to

$\mathfrak{c}$(deep greenish-blue) > $\mathfrak{b}$(olive-green) > $\mathfrak{a}$(greenish-yellow).

Occasionally small arfvedsonite grains occur together with dusty magnetite in the chalcedony masses.

Name : Orthophyric Comendite.

Soil : this rock yields a poor sandy grey soil.

Silica percentage : the SiO_2 percentage in this rock was estimated and found to be 76·12.

Closely allied in composition to the comendites are various rocks belonging to the orthophyres and pantellarites. To these classes belong the rocks now about to be described.

Fl.1. Loc.: Stafford's Rock, near Mt. Flinders.

Handspecimen: reddish-banded rock, aphanitic and showing flow-structure.

Microscopic texture: microcrystalline phenocrysts are imbedded in a microfelsitic (microaphanitic) base, partly isotropic and partly birefringent. The texture is minutely hiatal-porphyritic and micro-vitrophyric. The base predominates in amount (perpatic). The phenocrysts are microlites of soda-rich sanidine. The clear, colourless, and birefringent constituents of the base likewise consist of felspar, whereas the yellowish isotropic portion consists of a mixture of crystallites, globulites and glass. A few minute tetragonal prisms and bipyramids with very high refractive index and birefringence are present. They probably consist of zircon.

Name: though rhyolitic in general appearance, no quartz is visible, so that we cannot say whether the rock is acid or intermediate. It is best called "hypohyaline zircon-bearing felsite" allied to pantellarite.

Fl.2. Loc.: Stafford's Rock.

Handspecimen: whitish aphanitic rock with banded structure. A few megascopic felspar crystals occur in it.

Texture—Crystallinity: hypocrystalline. Grain-size very fine and even-grained base in each band. Fabric: trachytic; and porphyritic in microcrystalline phenocrysts immersed in a cryptocrystalline base.

Composition: the phenocrysts are corroded prisms of sanidine. The felspar of the base exists as microlites and crystallites. Skeleton-crystals are common. The rest of the base consists chiefly of isotropic material. The refractive index of the globulitic and glassy substance indicates the presence of much quartz. A few red specks of limonite, black grains of magnetite and zircon prisms occur. Some bands in this rock are coarser in grain-size than others.

Name: Trachytic Zircon-felsite, allied to Pantellarite.

Fl.4. Handspecimen: a dark greenish-black rock looking like bottle-glass, which occurs as a flow underlying trachyte-felsite in Kelly's paddock, near Ivory Knob. Much of this rock is beautifully spherulitic.

Microscopically this rock consists of an isotropic glass, which shows beautiful perlitic structure. A few phenocrysts of orthoclase occur in it. These often include albite lamellæ in parallel intergrowth, and sometimes zircon.

Name: Perlitic Vitrophyric Trachyte, or Perlitic Trachyte-obsidian.

The SiO_2 percentage was determined, and found to be 69·74, so that this glass probably has the pantellarite composition.

Fl. 11. Handspecimen: a reddish, aphanitic, banded rock showing flow-structure; very like Fl.1, and Fl.2.

Microscopic texture: hiatal-porphyritic phenocrysts are seen in a microcrystalline to microspherulitic base. The phenocrysts consist of anorthoclase; felspar also forms stellate groups of crystallites in the spherulitic base. Most of the base appears to have the composition of felspar. Yellowish globulites, a few minute green ægirite fragments, some magnetite grains, and ilmenite plates, and a few xenogenic biotite- and quartz-fragments constitute the accessories, which all together form less than 2 % of the rock.

The silica percentage was found to be 72 %, hence the base must contain quartz.

Name: Microspherulitic Quartz-bearing Soda-Rhyolite, allied to Pantellarite.

Fl.9. Loc.: Summit of Mt. Blaine.

Handspecimen: white, megascopically porphyritic trachyte.

Texture—Crystallinity: holocrystalline. Grain-size: uneven, with serial porphyritic phenocrysts in a microcrystalline base; dopatic. Fabric: trachytic to orthophyric.

Composition: the main constituent is felspar. The phenocrysts vary in size from mediophyric to mediiphyric. Their refractive index is always less than that of canada balsam. Carlsbad twinning is common, but, in addition, we have a shadowy extinction due to the interlamellation of two different felspars, and to ultramicroscopic twinning, chiefly the latter. The phenocrysts frequently show an orthopinacoidal parting, and a corrosion-rim of heterogeneous composition. Two cleavages occur, and are, in some crystals or in parts of certain crystals, quite rectangular, in others not rectangular, The latter portions frequently exhibit distinct albite twinning, and have a higher refractive index than the others. They consist of albite or a variety of anorthoclase near albite. This kind of felspar frequently forms a rim round the sanidine-like variety. The extinction of the sanidine-like felspar is 11°. We have, therefore, three closely related felspars, often mutually intergrown: (1) soda-orthoclase, (2) microcline-microperthite (anorthoclase), and (3) albite. These three felspars commenced to form at the same time, but the excess of soda in the magma probably led the albite to continue to form after the others finished. The felspar of the base has the refractive index of albite. Generally speaking, the microlites of nephilinitoid habit have the properties of anorthoclase, and those of prismatic habit the characters of albite. Some of the phenocrysts show incipient decomposition to kaolin and a clear isotropic material like analcite. The other minerals observed in the slide are: (a) magnetite in idiomorphic grains, forming about 2 % to 3 %, (b) zircon in idiomorphic prisms (acicular), forming less than 1 %, and (c) minute grains of a greenish pyroxene and of a yellowish mineral which is probably wöhlerite or eucolite, and also a few specks of deep blue pleochroic riebeckite.

Name: Soda-Trachyte, near Orthophyre.

Fl.14. Handspecimen: porphyritic white trachyte occurring near Fl.13, and forming an older flow.

Texture: porphyritic-hiatal with cryptocrystalline base, partly pseudospherulitic (strahlenkörnig), in part pilotaxitic.

Composition: the most abundant components are felspar and isotropic or nearly isotropic base. In addition a little magnetite, acmite and rutile are present. The felspar is of two generations. The first generation, that of the phenocrysts, consists of a soda-rich variety of orthoclase which sometimes includes lamellæ of albite. The phenocrysts may be idiomorphic, or corroded, or allotriomorphic. Several bundles of phenocrysts occur which are inclusions of a medium-grained bostonitic rock consisting wholly of felspar. There is no proper corrosion-rim round any of them, yet some have been rounded, and strands of base have filled hollows formed by corrosion. The extinction angle varies from 4° to 8°, and the cleavage is rectangular. Twinning is wholly on the Carlsbad plan, and only the faintest traces of shadowy extinction are seen in some. The form of the felspars is orthorhombic. Evidently the phenocrysts and groupings of phenocrysts are derived from some previously consolidated bostonite or lestiwarite. The fabric of the groupings approaches that of lestiwarite, but the crystals are not wholly allotriomorphic as in many lestiwarites. The felspar crystals of the base are minute needle-shaped microlites which are doubly refracting, and still finer crystallites which are practically isotropic. These minute needles can be seen with the high power in non-polarised light. The whole mass exhibits a faint shadowy, pseudospherulitic extinction when the nicols are crossed. A cloudy grey, practically isotropic, base exists interstitially between the fine needles; this may consist of still finer crystallites and globulites of felspar, with or without either cryptocrystalline quartz or some felspathoid. As the rock is slightly decomposed, staining tests are not of much use, and, the SiO_2 percentage not having been determined, the exact composition of this groundmass must remain unknown for the present. The acmite is greenish-yellow and feebly pleochroic as in the trachyte from the summit of Mt. Flinders. It is very sparingly represented. Magnetite occurs in idiomorphic corroded grains, also in minute amount. Minute violet grains of a highly refracting and doubly refracting mineral also occur very sparingly. These are probably a titanium mineral allied to rutile.

Name : Pseudospherulitic Trachyte-Porphyry.

Fl.16. Loc.: Mount Flinders, east side, forming the main mass of the mountain.

Handspecimen : porphyritic light-coloured whitish trachyte.

Texture holocrystalline, hiatal-porphyritic, with phaneric phenocrysts in an aphanitic cryptocrystalline base. The rock is perpatic, the phenocrysts forming less than 10 per cent. With the high power, the base is resolved into microlites and crystallites having a trachytic fabric.

Component minerals: the chief constituent is felspar. The phenocrysts consist of felspar, with glassy inclusions. The extinction angle makes 9° to 10° with the composition-plane of the Carlsbad twins, and the extinction is somewhat shadowy. Small lamellæ of albite occur in some. Cross-cracking, as in sanidine, is universal. These characters point to the felspar being soda-sanidine or anorthoclase. The crystals are irregular in outline, some or other of the faces being always mutilated. Sometimes they occur in a group, and often they are corroded. These features suggest that they are torn out of a previously consolidated rock, as in Fl.14. Orthoclase and anorthoclase form the bulk of the base. They occur in the form of stunted laths and squares (sections of square prisms); they show shadowy and almost straight extinction and Carlsbad twinning. Other minerals occur only in minute amount, and consist of (1) minute needles of ægirine-augite; (2) irregular grains of magnetite; (3) granules of hæmatite and reddish iron-ores. There is also a little interstitial isotropic material, and some interstitial birefringent colourless matter is also present. This may be chalcedonic silica.

Analysis: the chemical composition of the rock was determined.

	Per cent.		Mol.
SiO_2	69·32	...	1·155
Al_2O_3	16·06	...	0·158
Fe_2O_3	1·42	..	0·009
FeO	0·88	...	0·013
MgO	0·06	...	0·001
CaO	0·31	..	0·005
Na_2O	6·01*	...	0·097
K_2O	4·23	...	0·045
H_2O	1·09	...	—
TiO_2	0·62	...	0·008
	100·00		

* Some impurity accidentally got into the alkali, hence the Na_2O was estimated by difference.

The analysis computed in accordance with the American system gives the following norm—

	Per cent.		Per cent.
Quartz	17·58	Magnetite............	1·16
Orthoclase..........	25·02	Ilmenite.........	1·22
Albite.............. ..	50·83	Hæmatite	0·64
Anorthite............	1·35	Water..........	1·09
Corundum...........	1·12		

The rock therefore falls in Class i., Subclass i., Order 4, Rang 1, Subrang 4.

Magmatic name: Kallerudose.

Name: Porphyritic Soda-Trachyte.

Fl.12. A dark grey rock containing white fragments of trachyte-porphyry. The dark portion is a microcryptocrystalline to glassy lava which, under the high power, is seen to consist partly of crystallites, globulites, margarites and spherulitic tufts of crystallites.

The phenocrysts are idiomorphic and somewhat corroded. They are interesting as exhibiting in an excellent way the cause of the shadowy extinction of anorthoclase. Some crystals are composed of orthoclase and albite in parallel growth, each felspar being quite distinct. Others, in which the intergrowth is finer, must be classed as microperthite. In others again the extinction of the felspars is shadowy, but there is no evidence of intergrowth until the crystal is turned almost to the position of extinction, when it becomes faintly cross-hatched. Doubtlessly the shadowy extinction of anorthoclase, whether primary or induced by strain, is due to the interlamellation of two felspars and ultramicroscopic twinning in the plagioclase component.

All the rocks hitherto discussed are decidedly acid. They yield poor sandy grey soils.

2. *Trachytes*—(*b*) The True Trachytes.

Fl A. Lava from the summit of Mt. Flinders.

Handspecimen: greenish-grey rock, mottled like "mackerel sky," and consisting of dark greenish areas intergrown with light greenish areas. Macroscopically very fine-grained.

Microscopic structure.—Texture. *a.*Crystallinity: holocrystalline. *b.*Grain-size: rather even-grained, microcrystalline, with a few small phenocrysts. *c.*Fabric: trachytic, with well-marked flow-arrangement.

Mineral Composition.—The rock is composed essentially of felspar and ægirine-augite, with magnetite, apatite, and a little fluorite present as accessories, and some reddish iron-ore and brownish serpentine as decomposition-products. The felspar consists entirely of lath-shaped microlites (of tabular and prismatic habits), some of which show Carlsbad twinning. The composition-plane is in the direction of the length of the laths. The extinction is almost straight in sections parallel to *a*(100), and in sections parallel to *b*(010) the extinction angle varies from nearly straight in the direction of the *c*' axis to about 12° on the edge bc. Extinction is, however, usually shadowy, a feature due either to strain induced by close packing of the microlites, or more probably to ultramicroscopic twinning. The glassy clearness of sanidine, and the cross-cracking parallel to *a*(100) are characteristic properties. The cleavage parallel to *c*(001) is good. With some difficulty the following optical properties were determined by the aid of the selenite plate; 𝔞 and 𝔠 are closely approximated so that the felspar is nearly uniaxial. It is optically negative ($Bx_a = \mathfrak{a}$). The birefringence-colours of the felspar and the selenite plate add when the 𝔞 of the plate is inserted in the long direction of the laths, and subtract when inserted transversely. The prisms and tables are elongated on the face *c* along the *a*' axis, and the tables are tabular on *b*. These properties fix the felspar as being a soda-orthoclase or anorthoclase.

The ferromagnesian mineral is in the form of minute greenish rods and grains, abundantly distributed in the dark patches of the rock, there forming ophitic or pœcilitic aggregates; and it also occurs as the nucleus of small phenocrysts, whose outer zone is a yellowish, feebly pleochroic acmite. The greenish pyroxene has the pleochroism: 𝔞 dark sea-green, 𝔟 light leek-green, 𝔠 yellowish-green, and absorption-scheme $\mathfrak{a} > \mathfrak{b} > \mathfrak{c}$. When a selenite plate is introduced in the direction of the length of the crystals, the polarisation-colour is raised; hence $\mathfrak{a} = c'$; this was also found to be the acute bisectrix, hence the mineral is optically negative. The green pyroxene is undoubtedly *ægirine.* In the phenocrysts it is surrounded by a rim of yellowish or brownish nonpleochroic acmite with rather similar optical properties. The double refraction of the ægirine is about 0·050. Incipient decomposition to a brownish serpentine and to ferrite, with the occasional appearance of hornblendic cleavage, was noticed in the acmite.

Colourless, isotropic areas were noticed. Their refractive index was very low, and they probably consist of nosean decomposing to analcite and zeolites. Some nosean aggregates have been completely replaced by zeolites (natrolite and thomsonite).

Magnetite occurs in idiomorphic grains. Apatite occurs in stout acicular prisms interpenetrating both the pyroxene and felspar. Fluorite occurs in irregular grains, or aggregates of grains, known by their low refractive index, faint yellow or violet colour, and their isotropism. There are also a few grains of a bright yellow allotriomorphic mineral with high refractive index and low double refraction, probably *eucolite.*

Leaving out of consideration minor constituents, felspar forms practically two-thirds, and pyroxene one-third, of the total bulk of the rock.

Name: originally this was a nosean-bearing ægirine-anorthoclase-trachyte.

Chemical Composition:

	Per cent.	Mol.
SiO_2	60·58	1·010
Al_2O_3	18·06	0·177
Fe_2O_3	3·05	0·019
FeO	1·38	0·019
MnO	0·04	0·002 (MnO + NiO.CoO)
NiO.CoO	0·07	
MgO	0·23	0·006
CaO	1·74	0·030
K_2O	6·87	0·073
Na_2O	5·01	0·081
H_2O (at 100°C)	0·99	0·106 (H_2O at and above 100°C)
H_2O (above 100°C)	0·90	
TiO_2	0·83	0·010
Sum		99·75

Norm:

Quartz	1·50
Orthoclase	40·59
Albite	42·44
Anorthite	6·39
Diopside	1·68
Magnetite	2·09
Ilmenite	1·52
Hæmatite	1·60
Water	1·89
Sum	99·70

Chemical classification : Class i., Order 5, Rang 2, Subrang 3. Magmatic name : Pulaskose.

Fl.13. Loc.: one of the northern foothills of Mt. Flinders. It overlies the light-coloured trachytes, and is probably the last flow.

Handspecimen : dark aphanitic rock with the characteristic fracture and aspect of the andesitic and phonolitic trachytes(even fracture).

Texture : holocrystalline, microcrystalline, even-grained; fabric intermediate between typical trachytic and typical pilotaxitic.

Composition : felspar forms about 75 %, ægirine 20 %, and magnetite 5 %. The felspar consists chiefly of acicular microlites, but partly also of allotriomorphic grains. Carlsbad twinning is frequent; albite twinning occurs occasionally, and shadowy extinction from crowding or ultramicroscopic twinning is very frequent. The refractive index is almost that of canada balsam. These properties indicate that the felspar is chiefly anorthoclase (soda-microcline ?), but true soda-orthoc ase and true albite are present in smaller amount. The ægirine is not quite fresh, being sometimes in an incipient stage of decomposition to chlorite, and shows a tendency to develop uralitic cleavage. The pleochroism is not very strong, being $\mathfrak{a}$ (near c′) bluish-green, $\mathfrak{b}$ brownish-green, and $\mathfrak{c}$ yellowish-green; and absorption $\mathfrak{a} > \mathfrak{b} > \mathfrak{c}$. The extinction angle is about 3° behind. The double refraction is 0·050. It is, therefore, an ægirine-augite. Magnetite is abundant in rounded grains. A colourless, dull grey mineral, with low double refraction and a refractive index slightly above canada balsam, occurs interstitially between the felspar, and is probably nepheline.

Order of consolidation : the felspar is studded with minute included rods of ægirine The magnetite is corroded; felspar frequently penetrates ægirite in an ophitic manner. The order therefore appears to be—

Magnetite
Ægirine
Felspar (idiomorphic variety)
Felspar (allotriomorphic)
Nepheline

Name: Phonolitic Ægirine-Trachyte.

Chemical composition:

	Per cent.	Mol.
SiO_2	56·78	0·946
Al_2O_3	14·47	0·142
Fe_2O_3	2·80	0·018
FeO	6·05	0·084
MgO	0·34	0·008
CaO	2·47	0·045
Na_2O	8·67	0·140
K_2O	4·51	0·048
H_2O(at 100°)	0·56	
H_2O(above 100°)	1·70	
TiO_2	2·00	0·025
NiO	0·05	0·001
MnO	tr.	
Sum	100·40	

Norm:

Orthoclase	26·69
Albite	35·11
Nepheline	7·67
Acmite	8·32
Sodium Metasilicate	3·42
Diopside	11·00
Olivine	2·74
Ilmenite	3·80
Water	2·26

Chemical classification: Class ii., Order 5, Rang 1, Subrang 4.
Magmatic name: Umptekose.

Fl.22. Loc.: Little Liverpool Range.

Handspecimen: a dark greenish-black, utterly aphanitic rock, very abundant on the eastern fall of the Little Liverpool Range. This rock passes into a microcrystalline rock similar to the trachy-andesites of the Warrumbungle Mountains, and Fl.13, Mt. Flinders. Only the aphanitic variety was collected.

Texture: microcryptocrystalline, perpatic; the base being barely resolved with the high power. There seems to be little or no glass.

Composition: a few microscopic phenocrysts, visible with the low power, consist of sanidine-like felspar. The base consists of an even-grained mixture of sanidine or anorthoclase in lath-shaped microlites; idiomorphic grains of greenish-brown, strongly pleochroic ægirine augite; minute idiomorphic magnetite grains, and cryptocrystalline interstitial matter. The fabric is trachytic.

Name: Ægirine-Trachyte, dark variety allied to Trachy-andesite.

Soil: this rock yields a good soil, rich in magnetite which collects as black sand in the streamlets after rain.

Fl.24. Loc.: Governor's Rock, top of Little Liverpool Range.

Handspecimen: somewhat decomposed, reddish, trachytic rock.

Texture: even-grained; micro- to cryptocrystalline with pilotaxitic fabric.

Composition: the felspars are anorthoclase and oligoclase in equant and acicular microlites. The base is decomposed and kaolinised. The original soda-amphibole is decomposed to red iron-ore, which is left in ophitic (mossy) aggregates.

Name: Oligoclase-Trachyte.

Soil: sandy and poor. This formation covers a considerable area on the range.

Fl.19. Loc.: various places south of Engelsburg.

Porous (miarolitic) coarse-grained grey rock in handspecimen, not unlike some specimens of Gib syenite-pegmatite (bowralite). The rock, on account of its porous nature, is very difficult to section. The slice examined was greatly broken up, yet sufficient portions retained cohesion so as to show structure and composition.

Texture—Crystallinity: holocrystalline. Granularity: medium, uneven, serial-porphyritic, persemic. Fabric: hypidiomorphic-granular.

It appears like a coarse-grained rock, but in the interstices, between the idiomorphic large crystals, are smaller crystals of hypidiomorphic or allotriomorphic outlines.

Composition: the large crystals forming the main bulk of the rock are idiomorphic, and belong to two felspar-species, (1) *oligoclase* known by its refractive index slightly above that of canada balsam, and double refraction slightly higher than orthoclase; and (2) anorthoclase.

The oligoclase exhibits carlsbad, albite and baveno twinning; and also beautiful mechanical and optical zoning, the former due to bands of dusty material and minute sagenitic rutile needles, arranged parallel to the outlines of the crystals; the latter kind of zoning is less universal, and not of such constant character. It is due to the interlamellation of two or more kinds of felspar in the same crystal, the more acid zone being usually exterior, extinguishing practically straight, and the more basic zone interior, extinguishing at 5°. Occasionally the core and the outermost zone are identical in composition, and more acid than an intermediate zone. The more acid zones consist of orthoclase or anorthoclase, and in rare cases of albite. The second type of phenocryst behaves like orthoclase, but exhibits shadowy extinction and sometimes very feeble polysynthetic twinning. It, too, possesses mechanical zoning. It is evidently anorthoclase.

All the phenocrysts are crowded with inclusions of sagenitic, greenish to colourless, rutile needles. Some of the smaller interstitial needles behave like orthoclase but are probably a soda-rich variety. Others consist of light green or greenish-yellow, faintly pleochroic augite-acmite which is also full of rutile inclusions, and is decomposing to chlorite. The augite-acmite is almost idiomorphic; its extinction angle is fairly high, approaching that of diopside; and it frequently has developed a hornblendic cleavage (uralitic decomposition). A development of secondary arfvedsonite round the augite-acmite is frequently distinct, and is another point of affinity with bowralite (Mawson). The arfvedsonite is much more sparing. It occurs in allotriomorphic patches enveloping augite, and is also seen in irregular cavities associated with quartz, when it is probably formed in the pneumatolytic period of consolidation. Allotriomorphic ilmenite also occurs interstitially; it is largely decomposed to leucoxene. Strands and grains of chlorite and kaolin-like decomposition-products are in evidence between the crystals of ferromagnesian mineral. A little iron-ore is also present.

Name: Arfvedsonite-bearing Syenite-Pegmatite allied to Bowralite.

Note: this rock occurs in large bodies, not small veins. The exact field-relations have not been worked out. It decomposes, producing red or brown rich soil which supports luxuriant scrub.

Chemical Composition :

	Per cent.	Mol.	Norm:	
SiO_2	62·25	1·036	Quartz	2·34
Al_2O_3	15·49	0·152	Orthoclase	15·57
Fe_2O_3	5·44	0·034	Albite	64·98
FeO	0·15	0·002	Acmite	3·70
MgO	0·84	0·021	Diopside	2·16
CaO	1·82	0·032	Hæmatite	4·16
Na_2O	8·18	0·132	Hypersthene	1·10
K_2O	2·57	0·028	Ilmenite	0·46
H_2O	1·26		Sphene	4·31
TiO_2	1·85	0·024	Water	1·26
	99·85			100·04

Chemical classification : Class ii., Order 5, Rang 1, Subrang 4.
Magmatic name : Umptekose.

Fl.20. Loc.: The Elbow, Old Warwick Road, Little Liverpool Range.

Handspecimen : dark greenish-black, vitreous rock.

Texture : hemicrystalline, with microlitic phenocrysts in a glassy base. The fabric is hyalopilitic.

Composition : the microlites consist chiefly of sanidine (perhaps anorthoclase). Sparingly represented we have minute idiomorphic grains of greenish, faintly pleochroic ægirine-augite; black idiomorphic grains of magnetite, and a little ilmenite; also a few rods of zircon. The rest of the rock consists of a cloudy yellowish glass, which, from its frequent display of feeble polarisation, is probably undergoing perlitic devitrification.

Name : Vitrophyric Trachyte.

Note.—This rock was obtained beneath a sheet of basalt, overlying which there is a trachyte capping. The basalt is probably a sill, for it seems to diminish in grain-size towards the borders.

Fl.27. Loc.: Little Liverpool Range, eastern slope, on Old Warwick Road, at an elevation of 2,000 feet.

Handspecimen : a brownish-grey rock, with subconchoidal fracture, and consisting of white felspar masses in star-like groupings, embraced in a brownish matrix.

Texture: almost holocrystalline, uneven-grained, consisting of crystals of various sizes (all microscopic) ranging down to interstitial isotropic matter. The fabric is a variety of pilotaxitic, very close to panidiomorphic-granular.

Composition: the main constituent is felspar, the crystals of which exhibit shadowy extinction, and Carlsbad twinning. The refractive index is very slightly below that of canada balsam. The felspars are mostly tabular in habit, and almost idiomorphic, fitting beautifully into one another as in a mosaic. They consist chiefly of anorthoclase, but a little albite and oligoclase appear to be present also. Baveno and Manebach twinnings are present in some crystals.

Pyroxene is wholly absent, but a yellow mineral takes its place. This mineral is pleochroic from greenish-yellow to honey-yellow; it has a high refractive index, and a medium double refraction (about 0·018). It appears to be optically positive. Complex twinning is occasionally seen in it, and extinction is straight with the cleavage. It is sometimes stained with yellowish or brownish decomposition-products. Some of the small grains are square, and exhibit rectangular cleavage; others seem to have pyramidal terminations. It is probably a tetragonal mineral, isotropic sections being met with. One of its most remarkable properties is, that numerous individual grains of it lying within certain areas are optically continuous so that the felspar is ophitically embraced in it. In optical properties this mineral is nearest to meliphanite. Mr. Wright, Assistant Demonstrator in Chemistry at the University, has found beryllium in the rock; but in other respects, as, for example, the high TiO_2, the rock-composition would indicate that this mineral must belong to the lävenite group. There is no other mineral present which is rich in titanium; hence in this unknown mineral we must include the following molecules as determined from the norm: acmite 5·08, hypersthene 0·20, titanite 4·12, ilmenite 0·15.

Another yellowish-brown mineral present in the rock exhibits no pleochroism, and shows sometimes a fibrous radial structure. It is almost isotropic and appears to be chalcedony. Hæmatite is fairly plentiful, and appears to be secondary after cubes of magnetite. Chloritic and serpentinous decomposition-products occur more sparingly, and a little interstitial fluorite seems present.

The peculiar texture and composition of this rock indicate that it consolidated under the influence of pneumatolytic action. It forms a dyke in trachyte-tuffs.

Name: Panidiomorphic Soda-Trachyte.

ChemicalC omposition:

	Per cent.	Mol.	Norm:	
SiO_2	65·09	1·085		
Al_2O_3	14·43	0·141	Quartz	10·32
Fe_2O_3	3·21	0·020	Orthoclase	18·90
FeO	0·13	0·001	Albite	56·07
MgO	0·10	0·002	Acmite	5·08
CaO	1·18	0·021	Hypersthene	0·20
Na_2O	7·26	0·118	Hæmatite	1·44
K_2O	3·24	0·034	Titanite	4·12
H_9O	2·42		Ilmenite	0·15
TiO_2	2·50	0·031	Water	2·42
	99 56			

Chemical classification: Class i., Order 5, Rang 1, Subrang 4.

Magmatic name: Umptekose.

Note.—This rock will be further investigated when more and better material are obtained. The unknown mineral appears to be quite a new one.

3. *The Andesites.*

Fl.23. Loc.: near Hotel Reserve, Little Liverpool Range.

Dark vesicular andesite containing white, decomposing plagioclase phenocrysts which fall out in grinding the section.

Texture: holocrystalline, perhaps hypocrystalline. Fine-grained, with medium to coarse phenocrysts. Serial porphyritic, dopatic. Fabric, pilotaxitic intersertal.

Composition: the felspar phenocrysts consist of andesine; felspar forms the main constituent of the rock. The smaller crystals are mostly andesine, but some are distinctly oligoclase and albite. The andesine and oligoclase exhibit Carlsbad and albite twinning. Habit, tabular and prismatic, lath-shaped sections abundant. Some oligoclase crystals are nicely zoned. Optical zoning is most prevalent. Some are mechanically zoned, and outside the dusty zone of inclusions there is a border of anorthoclase. In one corner of the slide is seen an aggregate of large oligoclase phenocrysts which, in unpolarised light, appear a homogeneous mass of felspar studded with inclusions of iron-ore and decomposition-products, but which, between crossed nicols, is resolved into a cluster (xenolith of the same magma). Its appearance is very like that described by me in these Proceedings for 1907 (pp.611, 612, and Plate xxxii., fig.3).

Acicular crystals of a variety of hornblende have been present, but have only left their traces in masses of secondary magnetite. A little ilmenite and primary magnetite are present. Apatite is sparingly represented in minute needles. Kaolin and other dusty decomposition-products are abundant, and secondary analcite appears also to occur in the base.

If the yellowish isotropic material be not all the result of decomposition, a yellowish glassy base is present.

Name : Andesite.

Other specimens from the same spot are rich in specks of chloritoids, allophane, and delessite of beautiful blue and green colours.

Soil : black and fertile.

Fl.25. Loc.: dyke in trachyte-tuff near Anderson's, Little Liverpool Range.

Fine-grained, greenish, aphanitic rock which has a greasy lustre, and metallic ring like phonolite.

Texture: holomicrocrystalline, porphyritic in a few microscopic, rarely phaneric, phenocrysts; perpatic, with even-grained trachytic base.

Composition : the main constituent is felspar. The felspar phenocrysts consist of an acid andesine in idiomorphic, sometimes corroded phenocrysts. Carlsbad, albite, and pericline twinning are shown. The habit of the phenocrysts is tabular. The smaller felspar laths of the base consist of andesine, oligoclase, and perhaps anorthoclase, showing Carlsbad or albite twinning. Manebach twinning has been noted in some cases.

Augite is next in importance, constituting perhaps 10 % of the rock. It is of a light greenish, almost non-pleochroic variety, and occurs in idiomorphic, but slightly corroded, square prisms. The faces *a* (100), *m* (110), and *c* (001) appear to be well developed, and *b* (010) not so well developed. The prismatic cleavage is poor, but a marked cleavage parallel to *a* (100) exists in many crystals, and a parting parallel to c occurs also. Extinction angle $\mathfrak{c} : c$ about 45°. Optically +^ve^. A twinning parallel to a dome, probably (101), is well marked; contact twins, tw. pl. *a* sometimes occur, and a polysynthetic twinning parallel to *a* occurs in other crystals. This kind of twinning may be due to decomposition, for most of the augite is developing a hornblendic cleavage. Zonal banding occurs. The properties determined point to an augite lying between true augite and ægirine-augite. The double refraction is only 0·024, near that of diopside. Inclusions of a yellow, feebly birefringent mineral occur as rounded masses in the core of some augite crystals. The refractive index of these inclusions is high. They may consist of a variety of allanite. Magnetite occurs in fair amount (up to 5 %) as idiomorphic grains. Apatite occurs as stunted rods and long needles penetrating both felspar and augite. Decomposition-products, such as red-iron ores, chloritic staining, kaolin, etc., from alteration of augite and felspar, occur in large amount. No nepheline seems to be present.

Name : Alkaline Augite-Andesite.

Order of consolidation :

1. Magnetite ———
2. Apatite ————————
2. Augite (1st gen.) ————
4. Felspar (1st gen.) —————
5. Augite (2nd gen.) ————
6. Felspar (2nd gen.) ————

4. *The Basalts.*

Basalts abound on the Darling Downs tableland, to the west of the Little Liverpool Range. Basaltic eminences also occur east of the Range, and on top of it. The basalts are typical, normal olivine basalts. In addition, great areas of country between the Fassifern district and the Birnam Range, near Beaudesert, are covered with coarse-grained dolerites which closely resemble the gabbros of the D'Aguilar Range, north of Ipswich. These dolerites represent sills intruded into tuffy sandstones of Trias-Jura age. One of them (Fl.21) is selected for description.

Fl.21. Dark, coarse-grained gabbroic rock occurring as xenoliths in a decomposed dolerite-laccolite near Milora State School. The xenoliths are of the same magma as the main rock. These rocks are probably older than the trachyte-series.

Texture: holocrystalline, coarse and uneven-grained, magnophyric. Hypidiomorphic granular fabric. The rock looks fresh in handspecimen, and is very hard to break; but the abundance of zeolites in the section shows that it is somewhat decomposed.

Composition—Felspar: some of the more decomposed crystals have the composition of anorthite (extinction angle 45°), but other fresher crystals (one of which showed symmetrical Carlsbad and albite twinning) have an extinction angle of about 24° in symmetrical sections, indicating labradorite. The decomposing anorthite crystals contain strands and irregular masses of analcite; they are probably only altered labradorite. Analcite is abundant, amounting to probably 10% of the rock in area. Some of it appears primary, just as in the Prospect dolerite, and shows crystalline outlines. Anomalous double refraction sometimes occurs in it. The felspars possess Carlsbad, albite, and sometimes pericline twinning. The zeolites, thomsonite, mesolite, and natrolite, all occur in fibrous radial aggregates associated with analcite. Sericite also occurs. These are all decomposition-products of the felspar.

Augite occurs in hypidiomorphic crystals of a light brownish colour inclining to salmon-pink. The extinction angle is about 45°, but in some crystals undergoing uralitic decomposition and developing hornblendic cleavage it is only about 20°. The augite is studded with idiomorphic magnetite inclusions. It appears somewhat titaniferous.

Minor constituents: ilmenite and titaniferous magnetite occur in about equal proportions. Red iron-ores secondary after augite, magnetite, and ilmenite also occur. A little serpentine and leucoxene have also been noticed. Olivine has not been present in the rock at all.

Name: it is clearly an altered soda- and titanium-rich augite analcite gabbro, and the weathered doleritic matrix must be looked upon as a hypabyssal analcite-dolerite without olivine. Near Teschenite.

Soil: rich brown and black soils.

Note: by the inclusions of one mineral in another, the order of consolidation is found to be—

1. Magnetite and ilmenite
2. Augite
3. Felspar
4. Analcite

Apatite is wholly absent, a rare thing in this rock-type.

Summary.

The Flinders volcanic rocks present the following peculiarities:

1. They are nearly all intermediate, approaching phonolitic rocks in chemical and mineralogical composition.

2. They have partially crystallised at a depth before further earth-movements caused their refusion and expulsion; hence the coarsely crystalline xenoliths occurring in them.

3. They invariably contain pneumatolytic minerals, *e.g.*, arfvedsonite, zircon, rutile, etc.

The Fassifern alkaline volcanic rocks have the following features:—

1. They vary in basicity, from the most acid to the most basic, ranging from comendites to what are practically ali-basalts (alkaline basalts).

2. Xenoliths due to inclusion of partially consolidated portions of the same magma occur in both acid and basic rock-species.

3. Evidences of pneumatolysis are abundant; in the commoner rocks they are met with in the minerals zircon, rutile, arfved-

sonite and fluorite; and amongst the rarer rocks we get pegmatites carrying arfvedsonite, rutile, zircon, and fluor, panidiomorphic trachyte with meliphanite(?), fluor, zircon, chalcedony, etc.

4. Abundant tuffs, breccias and highly vescicular lavas are represented (also at Mt. Flinders).

5. Oligoclase is a commoner ingredient in the Fassifern trachytes.

The points specified show that the magma was rich in water, fluorine, etc.

The greater richness of the soil in the Fassifern district than in other trachyte areas is readily seen to be due, in part at least, to the presence of oligoclase (carrying lime) in the trachytes, and to the fact that ægirine-augite (carrying MgO and CaO) largely replaces true ægirine.

The occurrence of alum in the Mt. Flinders breccia proves the presence in it of sulphur-rich minerals such as nosean. Further, the cobalt stains in the breccia and the amount of combined nickel and cobalt oxides (0·07 %) in the lavas, show that here again, on approaching the D'Aguilar Range, we enter a nickeliferous province, as I have indicated in my paper on the "Geology of the East Moreton and Wide Bay." Such a high percentage of NiO.CoO is not met with in the New South Wales trachytes.

It might further be pointed out that in the Flinders-Fassifern alkaline province—

1. The same minerals are met with as in other Australian alkaline provinces, though the lime-percentage is slightly greater.

2. The same volcanic sequence occurs, and the same associated rocks as in other alkaline provinces. The monchiquites of the Nandewars and essexites of the Mittagong area are here represented by analcite-dolerite (teschenite), and this rock is older than the trachyte. After this the sequence is from the more acid to the more basic.

3. The craters of eruption are situated mainly along two great fissures which bound the senkungsfeld area of the Walloon Coal Measures, in the same way as I have hinted that the Warrumbungles may be a senkungsfeld area, and I have shown that a subsided area exists west of the Nandewars.

4. The Fassifern trachytes lie immediately to the east of the Darling Downs uplifts just as—

(a) The Glass Houses lie east of the Woodford raised peneplain.

(b) The Yandina trachytes east of the Blackall Range and Cooran uplift, and west and south of the Woondum horst.

(c) The Nandewars west of the New England uplift.

(d) The Clarence trachytes east of the New England uplift.

(e) The Warrumbungles some distance west of the New England uplift, just as Mt. Flinders lies some distance east of the Darling Downs uplift.

(f) The Gib and the Canoblas west of the Blue Mountains uplift.

Much work has to be done before the plains and peneplains mentioned can be properly correlated, but in this work the trachyte-lines will be a source of valuable information.

EXPLANATION OF PLATES I.-VI.

Plate i.

Map of the Mt. Flinders and Fassifern Alkaline Area.

Plate ii.

Map of Mt. Flinders.

Plate iii.

Fig. 1.—View of Mt. Flinders from slopes of Mt. Blaine, looking south.

Fig. 2.—The Alum Cave, Mt. Flinders.

Plate iv.

Mt. Blaine, looking north.

Plate v.

Fig. 1.—View of Mt. Goolman and Ivory's Rock from Kelly's house, looking east.

Fig. 2.—View of Mt. Blaine, looking east-south-east from Kelly's paddock.

Plate vi.

Fig. 1.—View of Stafford's Rock, looking south.

Fig. 2.—View of Mt. Flinders, looking south-east from Kelly's paddock.